MINE RECLAMATION USING DREDGED MATERIALS AND COAL ASH

Preliminary Findings[1]

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Bark Camp high wall, 1996

Bark Camp high wall, 2001

ABSTRACT

This is the final report of the project begun in 1995 by Pennsylvania DEP's Bureau of Abandoned Mine Reclamation and the NY/NJ Clean Ocean And Shore Trust, a bistate marine resources commission, to use dredged materials from New York Harbor, amended with pozzolonic wastes, to restore an abandoned strip mine in west-central Pennsylvania.

Since 1998, three quarters of a million tons of amended dredged materials from the Port of NY/NJ were used to return 11,000 feet of a double highwall 120 feet in height to its original contours of 75 years ago. The material was screened and pre-amended for shipping at port-side, railed to the mine site, further amended to initiate a pozzolonic reaction, and placed in lifts to recreate the hillside's original contours, covered with a manufactured soil and planted. Water quality testing from surface run-off and six deep wells below the site over three years showed non-detects for all organics, pesticides, VOCs and semi-VOCs. TCLP testing of the cured material yielded the same results. Over-wintering trout have returned to Bark Camp run below the site for the first time in decades.

The United States moves nearly half a billion tons of dredged materials from its navigational channels annually, while hundreds of individual dredging projects, such as those to restore reservoir capacity, can generate additional hundreds of millions of tons each. The US also

[1] The Final Report for this project was in production at the time of submission of this paper. We here present the project and our preliminary results in advance of the official final report

produces some 130 million tons of coal fly-ash annually. The following examines particulars of each component of this project and summarizes our preliminary findings.

BACKGROUND

Site. The project using fill manufactured from dredged materials and coal fly ash is located on Bark Camp Run, a small tributary to the Bennett Branch of the Sinnemahoning Creek near the town of Penfield in Clearfield County, west-central Pennsylvania.

The Bark Camp Mine Reclamation Laboratory began in the late 1980's as an effort to develop design criteria for artificial wetlands constructed to treat acid mine water. Over the years since then, it evolved into a mine reclamation research/demonstration laboratory, where several important mine reclamation demonstrations have taken place, including the use of fly ash as fill, and the creation of artificial top soils.

The watershed in the state forest portion was extensively mined prior to 1980. Abandoned, unreclaimed surface mines follow the contour of the valley on the west side of the stream from the headwaters to about halfway down the valley. Two coal seams were mined in some places, leaving a 120 foot high wall in two lifts along 11,000 feet of hillside.

Underground mining occurred under the hills on both sides of the valley. The mines were abandoned in the mid 1980's and the entryways closed by pushing rock and spoil material into the surface entrances. Portions of the mine down-dip from the entries, filled with water. The up-dip portions (more than a mile in length in places) flowed into the pool and overflowed through the entries. The resulting discharges from both mines were acid and contained dissolved metals. Sometime in the mid 1980s, the operator abandoned the site.

Process. The project involved dredging in marine and coastal waters in NY/NJ, and transporting the dredged materials to a portside facility located in New Jersey. There, the dredged materials were dewatered, off-loaded, screened to remove oversized debris, pre-amended to stabilize for transport, and loaded into railcars for shipment to Bark Camp. The pre-amended materials were off-loaded from the railcars at the Bark Camp rail siding and hauled in off-road trucks to the processing pad at the mine facility. The pre-amended materials were processed with additional admixtures to create the final manufactured fill product. This fill was spread and compacted in lifts along designated segments of the highwall. Details of the operation are presented in subsequent sections of this paper. This project is notable for several reasons: the magnitude of the AML features addressed; the prevention of AMD at its source, and its place in a larger scheme of the beneficial use of waste materials presently otherwise disposed of.

Abandoned Mine Lands. In 1995, The Bureau of Abandoned Mine Reclamation and the Bureau of Solid Waste and Land Recycling in Pennsylvania's Department of Environmental Protection were approached to examine the possibility of the beneficial use of dredged material in mine reclamation. Pennsylvania is noted for its share of AML problems and their magnitude, estimated as requiring $15 billion for the basic remediation of over 5600 sites deemed a human health hazard out of their 9000 abandoned mines. Pennsylvania has over 800 incidents of mine subsidence each year; 45 underground mine fires (including the famous Centralia Mine Fire which has burned for 39 years) and 3000 miles of AMD impacted waterways. The fill requirements of these features are immense. Several individual sites (like the Jeddo Mine Tunnel and the twin 32-mile-long crop falls in the anthracite region) require in excess of one billion cubic yards of fill each. The state's fill requirement is in excess of 10 billion cubic yards. Having successfully experimented with the sealing of AMD-causing formations with fly-ash grouts PaDEP suggested the examination of the use of the dredged material as an aggregate in a manufactured fill bound with pozzolonic fly ash, another waste disposal problem.

Dredging. On average, the United States annually dredges and disposes 300 million tons of sediments from its ports, dams, reservoirs and navigational channels. However, individual projects exist with like volumes, such as the deepening of channels to accommodate new generation shipping vessels, and the restoration of silted up hydropower reservoirs. The Port of New York/New Jersey alone is expected to generate 250,000,000 tons of dredged material from the deepening and maintenance of its navigation channels over the next 40 years. Dredged material is significant not only for the remarkable volumes generated (for general purposes, a ton of dredged material is equal to one cubic yard of volume) but for the fact that the means of their disposal- ocean dumping- is ceasing to become an option because of concern over the potential bioaccumulation of trace agricultural and industrial contaminants in the marine food chain. The maritime community saw the cost of dredging and disposal go from $5 per cubic yard to $125 practically overnight. Maintenance dredging went undone, container ships and tankers had to carry partial loads or transfer cargoes to off shore barges. The 165,000 port jobs and annual $20 billion contribution to the region's economy was threatened. Relocation of major shipping companies to deeper ports would have impacted the entire northeast region whose imports and exports are served by the Port of NY/NJ.[2] This regulatory change has impacted the regions economy and employment, imports/exports and transportation patterns, requiring the development of an affordable, long term upland disposal option.

Coal Fly Ash. The physical and chemical properties of coal fly ashes have been studied for over 20 years and their pozzolonic (cementitious) binding properties are well known, being a significant additive in Portland cement. The United States produces an estimated 130 million tons of fly ash annually in the burning of coal that generates half the nation's electricity. However, less than one third of it is used in manufacturing while the rest is disposed of in over 750 sites around the country, from lined landfills to massive open stockpiles. Coal ash disposal has been relatively free of federal regulation, but recently, however, coal ash only narrowly escaped significant regulatory oversight from the US Environmental Protection Agency, with the likelihood of increased scrutiny over the next year.[i] The amount of ash generated will only increase due to energy demand and Clean Air Act requirements for the addition of more scrubbing materials (like lime) during the combustion process. Coal ash's well known property of expansion during chemical hydration also limits the amount that can be used in cement manufacture.

Project Concept. In considering these three problems a pattern of complementarity emerges: massive volumes of disposal materials / massive voids requiring fill, acid generating voids / alkaline materials requiring confined disposal, a problematic wet material / a binder that initiates hydration reactions. It was decided to test the use of dredged material as an aggregate in a fly-ash bound manufactured fill, to restore the original contours of a hillside that was striped into a 120 foot high-wall extending for eleven thousand feet. Since the issues of abandoned mine lands and coal fly ash used in their remediation are well known, this paper will emphasize the dredged material portion of the project. As important as the physical description is a brief treatment of public attitudes towards such projects, and the means of their financing.

[2] It should be noted here that known or suspected threats to human or environmental health by the disposal of dredged sediments in the ocean is a separate issue from the policy decisions made in the region.

METHODS AND MATERIALS

Dredged material. *Dredged material* is the generic term for the wet sediments removed, or dredged, from navigational channels, reservoirs and so on. [3] Because they are in aquatic environments, they are mostly water (usually 65%) with the remaining solid portion being the constituent sediments of natural erosion processes and storm water runoff. Depending on their location along watercourses, the solid potion of dredged materials may range from sand, to a mixture of sand, silt and clay, and up to 7% decaying organic plant matter (common mud). We are here largely concerned with the later characterization, since clean sand is generally used for beach replenishment or aggregate, and particle size is a key factor in contaminant adsorption. This mud is often described as black mayonnaise, its small particle size making it readily adhere to surfaces and its decomposing organic material giving off the smell of hydrogen sulfide. This is true of pristine wetlands sediments as well and is not an indicator of their relative environmental health as sediments. Being mostly water, the material sloshes readily and must be transported carefully, even in barges. Their physical properties are important in considering their handling and transportation, and in their perception by the public. Coming from areas adjacent to human activities, these materials contain a certain amount of natural and man-made debris, and trace contamination of agricultural and industrial runoff, including metals and organic compounds including dioxins and PCBs. The issue of sediment contamination is complex but will be presented here in brief.

Contaminated Sediments. Many of the chemical substances of concern came into question recently with the ability to detect concentrations at parts per trillion and quadrillion. The difficulty arises when societal concerns meet (or ignore) science. The toxicity of a substance involves a complex set of circumstances including species, exposure, pathways, age and sex of subject and so on. Controversy rages over the health impacts of even the more notorious contaminants like dioxin. It is not known what level of trace concentrations of contaminants pose a threat, to humans or the marine environment.

Five major types of pollutants are found in sediments[ii]:

Nutrients, including phosphorous and nitrogen compounds such as ammonia. Elevated levels of phosphorous can promote the unwanted growth of algae. This can lead to the amount of oxygen in the water being lowered when the algae die and decay. High concentrations of ammonia can be toxic to benthic organisms.

Bulk Organics, a class of hydrocarbons that includes oil and grease.

Halogenated Hydrocarbons or **Persistent Organics,** a group of chemicals that are very resistant to decay. DDT and PCBs are in this category.

Polycyclic Aromatic Hydrocarbons (PAHs), a group of organic chemicals that includes several petroleum products and byproducts.

[3] Dredged Materials should be distinguished from sludge (treated human waste) and other materials, the names of which are often inaccurately applied.

Metals, including iron, manganese, lead, cadmium, zinc, and mercury, and **metalloids** such as arsenic and selenium.

Interestingly, the banning of ocean disposal of dredged materials is in some ways more the result of the continuing momentum of anti-ocean disposal actions over the last century regarding far more obnoxious substances. Ocean disposal of garbage was banned in the 1930's, disposal of acid waste some time after that, treated sewage sludge in the 1980's, and the burning of wooden marine debris out at sea was stopped in the 90's. Now, ocean disposal of even mildly contaminated sediments has been virtually phased out, and it seems that even virgin clay material from the last glaciation will not be ocean disposed.

PaDEP has established a pass/fail standard for maximum levels of contaminants acceptable for this demonstration. A complete list of over 300 analytical parameters sampled for the dredge material project available via their website:
http://www.dep.state.pa.us/dep/DEPUTATE/MINRES/BAMR/bark_camp/barkhomepage.htm

Analytical parameters are general chemistry, inorganics, organics, pesticides and PCB's and are also listed in alphabetical order in the website. Perhaps most easily understood, Pennsylvania will not accept material categorized as hazardous. Ceilings for dioxin levels are at 530 parts per trillion and for PCBs at 4 parts per million (mg/l).

Disposal options became limited to physical decontamination of the sediments, upland disposal, or their beneficial use in brownfields remediation, wetlands restoration or even as daily landfill cover.

Coal Ash. The manufacture of cementitious grouts from ashes for large applications relies upon alkali activation to initiate hydration reactions. Structures dating from ancient Roman and Greek cultures, many still standing today, were constructed from this type of cementitious material. A pozzolan can be defined as a siliceous or siliceous and alumnus material, which possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

From the point of view of dredged material disposal, this project amounts to contaminant sequestration. Fine particle sizes in dredged solids provide immense surface areas. A gram of mud has 760 square meters of surface area, providing myriad sites for the attachment of contaminants and the cause of concern when the material is digested by benthic organisms. When the material is hardened into a cement matrix, the same gram of material has a surface area of about 1 square inch, about one-millionth that of the unconsolidated material. The reduction in surface area available to chemical attack alone would be a significant safeguard to the leaching of contaminants. But Toxicity Characteristic Leachate Testing show that the material is chemically bound in the cement matrix, as described below.

PROJECT OPERATIONS

It is important to note that the demonstration site was chosen strictly for scientific reasons and not logistical ones. In many ways Bark Camp is not an ideal site, requiring much re-handling and transportation of the material on site.

The dredging is performed utilizing a dredge-plant mounted on a spud-barge and equipped with various types of clamshell buckets, and two hopper barges. Local tug service is used to transport the hopper barges to and from the transfer facility.

Off-loading of the dredged material at the facility is accomplished utilizing a 50-ton crane equipped with a clamshell bucket. As necessary, the loaded barges are moored at the facility to allow the sediment to settle for dewatering of the barges prior to off-loading. Water decanted from the loaded barges is pumped through a particulate filter to portable frac-tanks. After an adequate period of settling, the water in the tanks are tested for compliance with discharge criteria contained in the Water Quality Certificate. Upon confirmation, the decanted water is discharged from the tanks to the local waterway.

The raw dredged material is off-loaded into a large receiving hopper and through a series of screens to separate debris from the sediment. This debris includes tires, pilings, timbers, large metal objects, concrete, and similar unsuitable materials and is staged for transport and disposal at an alternate approved disposal facility. The dredged material is placed into a pugmill where it is mixed with coal fly ash to pre-amend (physically stabilize) the material for transport to Bark Camp. The raw material is solidified to ensure that no free liquid is present in the material that may leak out or shift the load during transport. From the pugmill, the pre-amended material is discharged via a radial-stacking conveyor to a temporary storage area. The material is loaded from the stockpile into 110 ton gondola rail cars for transport to the Bark Camp Facility.

The pre-amended dredge material is transported to the Bark Camp facility via rail. All rail cars are covered with tarps during transport. The railcars are unloaded at Bark Camp utilizing an excavator located on an elevated off-loading structure. The material is placed directly into off-road trucks and transferred to the final processing area. There the material is blended with additives in a pugmill system according to a pre-determined mix design, and discharged onto a radial stacking conveyor. The final manufactured fill is transported utilizing off-road trucks to the reclamation area of the highwall. The fill is spread in two-foot thick lifts with a low-ground-pressure bulldozer and compacted using a vibratory roller.

Sampling And Testing Protocol. This project is conducted pursuant to all local, state, and federal regulations applicable to the dredging, processing, transport, and beneficial use of the dredged sediments and additives. Certain permits were required for each location and/or operation of the project. The testing protocols include full Toxicity Characteristic Leaching Procedure (TCLP), organics, inorganics, metals, pesticides, herbicides, PCBs and dioxin/furans. Composites taking during shipping undergo TCLP and analysis for PCBs and dioxins. The final product undergoes the Synthetic Precipitation Leaching Procedure (SPLP).

Quality Control measures for this project included characterizing the chemical and/or physical properties of the raw dredged sediment and any additives utilized in the treatment process prior to commencing dredging. The physical and chemical properties of the additives were determined from testing and analytical results provided by the generators of these materials. Vendors supplying coal ash products were required to demonstrate that the ash materials meet the PADEP Module 25 chemical criteria for ash placement in mine reclamation. Additionally, Material Safety Data Sheets (MSDS) that are available for these materials are kept on file in the administrative office at the Bark Camp facility.

The chemical analysis protocol for the dredged sediment intended for Bark Camp consists of three stages. These include the core sampling and analysis of in situ dredged material (Stage I); the sampling and analysis of the dredge material at the portside offloading facility, which is intended to confirm that the material being shipped is similar to the in situ materials (Stage II); and the sampling and analysis of the treated materials at the Bark Camp facility to assure that the manufactured materials comply with the criteria established in the Beneficial use Order (BUO), (Stage III).

The sampling and analysis is conducted in accordance with the requirements of the BUO and the New Jersey Department of Environmental Protection (NJDEP) guidance manual entitled The Management and Regulation of Dredging Activities and Dredged Material in New Jersey's Tidal Waters; October 1997. The New Jersey manual (the "Guidance Document") specifies sampling and analytical requirements for upland disposal and beneficial use of dredged materials in the State of New Jersey. The manual specifies sampling procedures and frequency requirements, target analyte lists, analytical test methods to be used, and acceptable method detection limits for in-situ sediment samples.

A Sampling and Analysis Plan (SAP) for the in situ sediment is prepared for this project and submitted for the NJDEP and PaDEP's review and approval. Individual core samples of the in situ sediment are taken to the proposed project depth plus allowable over-dredge. Composite samples are prepared from the individual core samples. The individual core and composite samples are subjected to the analysis specified in the Guidance Document and the approved SAP.

Bench tests utilizing the sediment from the in-situ testing and various percentages of additives are performed to simulate the creation of the manufactured fill. The bench test product samples are analyzed in order to chemically and physically characterize the manufactured fill and to determine the ability of the fill from each mix design tested to stabilize chemical constituents found in the in-situ sediment. The analytical and test results for the Stage I in-situ sediment samples are submitted to the NJDEP and PaDEP for their respective review and approval. NJDEP issues the Waterfront Development Permit permitting dredging and PaDEP issues written approval for use of the dredged materials at Bark Camp.

Stage II testing occurs at the portside facility and is performed to confirm that the pre-amended dredged material is physically and chemically characteristic of the material sampled in Stage I. This confirmatory sampling is performed pursuant to the BUO, at a frequency of one composite per 25,000 cubic yards of dredged material. Accordingly, one (1) composite sample is chemically analyzed and geotechnically tested pursuant to the requirements specified in the BUO. The analytical and test results are reported to the PADEP for its review and information.

The final stage (Stage III) of the QA process is performed after the final amendment of the dredged sediment at the Bark Camp facility. One (1) composite sample of the manufactured fill is obtained pursuant to the BUO requirement of one composite sample per every 25,000 cubic yards of material. The composite sample is chemically analyzed and geotechnically tested pursuant to the specific requirements specified in the BUO for the manufactured fill. The analytical and test results are reported to the PADEP for its review and information.

A tabular summary of the analytical results for a set of in situ sediment samples, the pre-amended (portside) dredge material, and the manufactured fill placed at the Bark Camp facility are presented in the above listed PADEP website. A copy of the geotechnical test results of the manufactured fill sample is also presented there. These data demonstrate that the technology producing the manufactured fill derived from the dredged material has effectively stabilized the chemical constituents present in the in-situ dredge material, and that the manufactured fill is physically competent as an engineered fill material suitable for use in mine reclamation.

Quality Assurance measures (Stages II and III) for this project are implemented to confirm that the chemical and/or physical properties of the pre-amended dredged material transported to Bark Camp and the manufactured fill are similar to that of the in situ sediment sample properties.

CONCLUSIONS

The following conclusions can be made from monitoring the material first placed at Bark Camp three years ago and monitored since, and the material placed since then.

By adding and mixing the dredged material with specific quantities and sources of coal ash, the dredge material was successfully pre-amended at the portside facility, rendering a material that could be handled and transported by common earth handling techniques and equipment.

All railcars arriving at Bark Camp were successfully off-loaded at the rail siding with little need to modify the equipment or techniques planned for this aspect of the project. Laboratory chemical analyses and geotechnical test results indicate that the processes creating the recyclable fill manufactured at Bark Camp have successfully solidified and chemically stabilized the dredge material.

Over 80,000 analyses of dredged material products were performed by PADEP alone, from pre-dredging sampling to surface and ground water monitoring. DEP analyzed for over 250 substances in most of the samples even though only a small percent of the analytes had reportable results. For three surface and six groundwater-monitoring points, 81% of the analytes were not detected in the DEP tests.

The long-term ability of the manufactured fill to sustain these properties will be monitored via visual observations and groundwater & surface water quality monitoring at the Bark Camp facility by PADEP.

The project has had some significant benefits. The site, which was a disaster before DEP began to use it as a research facility, has been substantially improved. Surface runoff from the site has been controlled. The coal silt and refuse has been disposed in a safe manner. The abandoned surface mines have been returned to the original contour. All this was accomplished at little cost to the Commonwealth. Further, the placement of the fill material in the surface mines is sure to reduce the amount of water seeping into the deep mines. This should show an improvement in surface and groundwater quality during periods of normal stream flow. Synthetic Precipitation Leaching Procedure (SPLP) testing of the final product emplaced in the high wall shows non-detects for metals and organics

Water quality testing from six deep wells below the site and surface water collection points all pass drinking water quality standards. Water quality test points, maps and results are available at:
http://www.dep.state.pa.us/dep/DEPUTATE/MINRES/BAMR/bark_camp/WaterQdata/WaterQ.htm

The manufactured fill project has had no negative impacts on surface or groundwater quality. The project site has experienced severe drought conditions over the past two years so there are presently no measurable positive water quality impacts to report.. The stream flows are lower than normal fed in a large part by groundwater affected by coal mining. The discharge from the deep mines has been fairly constant over the same time frame. The few analytes that exceed the allowable limits are mostly mine water related and exceeded the limits before any material was placed in the abandoned surface mines. Placement of the material has not changed the concentrations of those substances. In addition, runoff from the abandoned mines is below normal because of the drought conditions of the past few years.

A 2001 biological survey by the Pennsylvania Fish and Boat Commission shows significant stream improvement adjacent to the site. The report states “The most notable changes in the biological sampling can be shown at Station BC02 (near the mouth of Bark Camp Run). The qualitative macroinvertebrate sampling conducted in April 1982 revealed a total of 8 taxa with only 3 taxa from the orders EPT (ephemeroptera, Plecoptera, Trichoptera), indicating a stressed aquatic system". The May 2001 results showed 20 taxa with 10 taxa from the EPT orders. The improvement is attributed to the reclamation activity on the watershed.

Geophysical tests were conducted in October 1999 by Lamont Dougherty Earth Observatory, including Ground Penetrating Radar, resistivity, conductivity and seismic imaging. These tests indicate that the placed material is uniform, solid, and has no water moving below it.

Future projects using dredged material, pozzolanic alkaline ash and a lime activator would be a benefit to abandoned mine reclamation efforts. Key aspects to the successful completion of this project included: proactive community outreach and participation; the setting of scientifically valid standards for acceptable and unacceptable materials; site selection with sufficient baseline environmental data to adequately characterize the site, spanning periods of high precipitation and high stream flows as well as periods of low precipitation and low stream flows.

Risk Communication. It is difficult to understate the complexity of communicating the benefit of shipping mud from New York Harbor into central Pennsylvania. Given that the Commonwealth already accepts much of New York and New Jersey's solid waste, and that dredged material was vilified beyond any real threat to human or environmental health in the campaign to cease its ocean disposal, this task was especially sensitive, PaDEP is to be commended for an exhaustive effort in community outreach that preceded the project. Literally dozens of visits to gain background and to understand sensibilities were undertaken. PaDEP held several open houses regarding the project and worked closely with its Citizen's Advisory Committee to gain support for an honest assessment of this concept's potential.

Future Projects. This project was largely funded by a bond act passed in the State of New Jersey specifically to find solutions for the dredging issue, and by the Port Authority of New York/New Jersey. As stated above, Bark Camp was chosen for its scientific merits, and the operation was built around it, not the other way around. A future project would have to be sited in an area that balanced several considerations including: accessibility to rail, degree of impact on the local environment that is significant and remediable, availability of ancillary funding (like reclamation bonds); nearby sources of admixture and acceptance by the local community. The greatest cost-effectiveness and economies of scale are achieved by piggy-backing multiple missions onto single projects, such as AMD abatement, wetlands restoration, mine reclamation and dredged material and coal ash disposal.

The ability to beneficially use the hundreds of millions of tons of dredged materials and coal fly-ash produced world wide has unprecedented implications for the 560,000 abandoned mine sites in the United States

REFERENCES

[i] A Plan to Dump Coal Ash Adds Salt to a Wound, New York Times Business Section p1, April 14, 2000

[ii] EPA Office of Water website: http://www.epa.gov/OST/cs/